

Juvenile Salmon Baseline Studies in the Nisqually Estuary; 2002-2004 Results

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Abstract

The Nisqually River fall Chinook stock is one of the 27 stocks in the Puget Sound evolutionarily significant unit listed as threatened under the federal Endangered Species Act. Preservation and restoration of the approximately 5000-acre Nisqually River Estuary has been identified as pivotal for the recovery of Nisqually Chinook salmon. Beginning in 2002 the Nisqually Indian Tribe, and in subsequent years the Nisqually National Wildlife Refuge, have conducted research focused on spatial and temporal distribution of fish populations, co-occurrence between juvenile Chinook salmon of hatchery and wild origin, and pre and post-restoration monitoring in the lower Nisqually River and Estuary.

Research efforts have provided catch data from over 400 beach seine sampling events throughout the lower Nisqually River, estuary, and nearshore areas. Salmonid catch was primarily composed of juvenile hatchery Chinook but also included moderate numbers of unmarked Chinook, chum, coho, and pink juvenile salmon, and occasional catches of cutthroat and steelhead trout. Coded-wire tag analysis indicated that juvenile Chinook salmon caught in the Nisqually Estuary originated from hatcheries throughout South and Central Puget Sound. Collectively, catch data provided insight on regional fish life histories and estuarine habitat utilization.

Introduction

The roughly 5000-acre Nisqually River Estuary complex, having barely escaped large-scale industrial development in the 1960's thanks largely to conservation minded local citizens (USFWS 2004), represents one of the best examples of historic Puget Sound estuarine habitat (Copping 1990). The continued preservation of the Nisqually Delta ecosystem coupled with extensive restoration of altered estuarine habitat is the highest priority habitat action for the recovery of naturally spawning, self-sustaining Nisqually River fall Chinook (*Oncorhynchus tshawytscha*). The Nisqually Fall Chinook stock is one of the 27 stocks in the Puget Sound evolutionarily significant unit listed as threatened under the federal Endangered Species Act (NCRT 2002). Chinook salmon rear extensively in estuaries and are thought to be the most estuary-dependent of the Pacific salmonids (Aitkin 1998). The estuary is also important to the Nisqually winter chum (*O. keta*), one of the largest wild runs in Washington State (WDFW and WWTIT 2002), which are known to utilize the estuary for feeding and growth (Fresh et al. 1979; Pearce and Meyer 1982).

The Nisqually Indian Tribe has already restored over 40 acres of historic estuary in the Nisqually Delta and plans on restoring an additional 100 acres in the near future. In addition, the Nisqually National Wildlife Refuge (Nisqually NWR) recently finalized a Comprehensive Conservation Plan and Environmental Impact Statement that will guide management of the Refuge for the next fifteen years, the cornerstone of which is a plan to restore nearly 700 acres of estuarine salt marsh and tidal slough habitat. The restoration of the Nisqually Delta ecosystem represents a unique opportunity to study the response of organisms to a recovering system.

Since 2002 the Nisqually Tribe, and in subsequent years the Nisqually NWR, have conducted research focused on spatial and temporal distribution of fish populations, co-occurrence and diet overlap between juvenile Chinook salmon of hatchery and wild origin, and pre and post-restoration monitoring in the lower Nisqually River and Estuary. The information will be used to help develop and evaluate hypotheses about the response of fishes to management actions like restoration and to monitor trends in fish distribution and abundance. This paper is limited to a baseline analysis of juvenile salmonid ecology in the Nisqually River and Estuary, with a focus on Chinook of both hatchery and natural origin and chum salmon.

Methods

Study Area

The mouth of the Nisqually River is located in South Puget Sound, approximately 20 miles southwest of Tacoma and 8 miles northeast of Olympia. The study area includes the lower 2 miles of the Nisqually River, the Nisqually Delta, and approximately 0.25 miles of adjacent nearshore in both Pierce and Thurston counties. The delta includes the estuarine portions of three distinct lotic systems: Red Salmon Slough (RSS), McAllister Creek (MCA), and the Nisqually River (NIS).

To assess habitat utilization and life history diversity of Chinook salmon and other fishes and to facilitate regional comparisons with research being conducted in the Skagit (Hayman et al. 1996) and Snohomish (Rowse and Fresh 2003) watersheds, the estuary was divided into the following distinct habitat zones based on salinity and observed dominant vegetation: freshwater, forested riverine tidal, emergent forested transition, estuary emergent marsh, delta flats, and nearshore; hereafter referred to as fresh, forested, transition, marsh, delta, and nearshore zones (Figure 1, Table 1). The marsh zone was subdivided further into MCA marsh, RSS marsh, and NIS marsh to facilitate geographic comparisons. The Nisqually marsh zone was only sampled in 2004. Nearshore sample sites were limited and do not adequately reflect the diversity of the Nisqually Reach nearshore environment.

Sampling Methods

Field protocols were modeled after similar studies in the Snohomish and Skagit River systems (SRSC Research 2003; Rowse and Fresh 2003) in order to facilitate regional comparisons and compilations. Each zone was sampled at 1 to 5 sites (Table 1). Sites were representative of areas that could feasibly be sampled. Extremely complex habitats (i.e. logjams) and areas with fast current (i.e. mainstem river) could not be sampled and thus were not represented. Each site was generally sampled once every two weeks, from April-August in 2002, February-October in 2003, and March-October in 2004. Fish sampling was conducted using a standard 'Puget Sound seine' measuring 37m x 2m with a 2.4m bag of 6mm delta mesh, set by boat and hauled to shore by hand. Most sites were sampled between mid to high tide, and generally only one set per site was done on each sampling occasion. Salinity, temperature, conductivity, and dissolved oxygen were measured at each site immediately after sampling using a YSI Model 85 handheld meter.

All captured fish were enumerated and 10 fish of each species were measured by fork length at each site. On beach seine hauls with excessively large catches or especially muddy conditions, a subsample was taken and enumerated, and then proportionally expanded by species to estimate the unsampled catch. All captured coho and Chinook salmon were examined for clipped adipose fins. All unclipped and the majority of clipped coho and Chinook were "wanded" to detect coded wire tags (CWTs).

Data Analysis

Data from 2002, 2003, and 2004 were pooled for catch comparisons between zones because there was no evidence that the catch within zone varied between years for unmarked Chinook ($p=0.27$), hatchery Chinook ($p=0.86$), and chum ($p=0.11$). The observational unit for analysis was average catch per set (CPS) per zone per day. Log-linear Poisson regression was the first alternative in each regression and log-linear negative binomial was the second. All regressions showed overdispersion so negative binomial was used for all log-linear regressions. When sets were sub-sampled due to excessive catch, or catch loss occurred and was estimated, the regression was adjusted with a log effort offset. F-tests were used to test variable significance. The multiple levels of categorical variables were tested with t-tests for coefficient significance and F-protected for multiple comparisons. For all 3 species tested, the zone variable was at least marginally significant ($p \leq 0.059$) so multiple comparisons between zones were made. Average timing comparisons were done separately for different sample years because there was evidence of variability in average timing among the 3 sampling years for unmarked Chinook ($p<0.0001$), hatchery Chinook ($p=0.007$) and chum ($p=0.005$) (some of this variability could be due to differences in sampling season length between years). Average species timing was estimated using Gaussian regression. The response of catch day was weighted with CPS per day (expanded for effort if sub-sample). Length data from all three sample years were combined and were not adjusted for effort. Unmarked and hatchery Chinook mean lengths were compared with a t-test and variances in length were compared with an F-test.

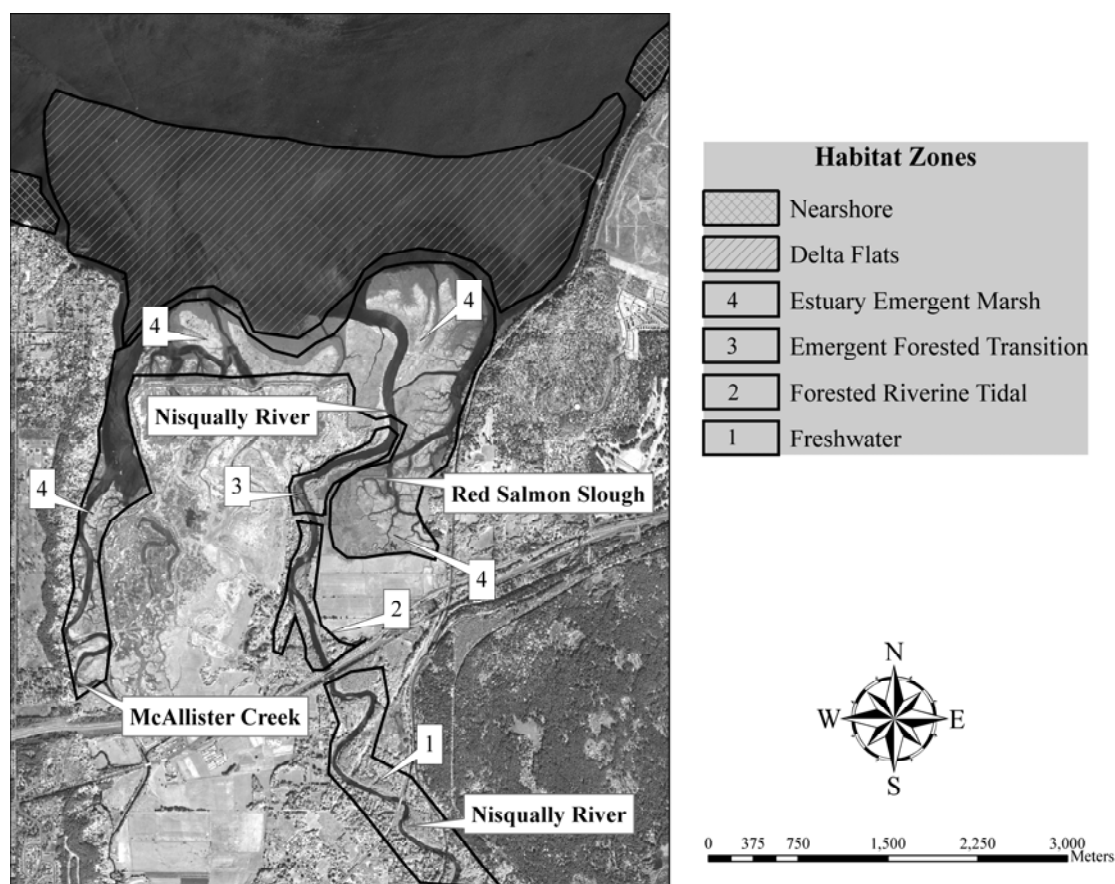


Figure 1. Nisqually River Delta habitat zones. Satellite image courtesy of DigitalGlobe.

Table 1. Nisqually Delta habitat zone salinity ranges and general identifying characteristics, with range in number of sites among years. Zone abbreviations used throughout this paper are shown in parentheses.

Habitat Zone	Salinity Range	Characteristics	# of sites
Freshwater (fresh)	0.0	Forested slow water habitat on mainstem Nisqually without tidal influence	1-2
Forested Riverine Tidal (forested)	0.0-0.3	Riparian forest, mud/silt substrate, and tidal influence	1-2
Emergent Forested Transition (transition)	0.1-2.0	Scrub/shrub and marsh vegetation, mud/silt substrate, and tidal influence	2
Estuary Emergent Marsh (marsh)	2.8-25.0	Low and high salt marsh vegetation, mud substrate, and full tidal influence	NIS (2004 only) 2
			MCA 1-5
			RSS 3
Delta Flats (delta)	18.0-28.0	Sparse to no vegetation, mud and/or gravel/cobble substrate, and large tidal fluctuations	4-5
Nearshore (nearshore)	25.0-30.5	Areas outside of Nisqually Delta, vegetation and substrate variable	1-3

Results

Total catch from all beach seine sets in research years 2002-2004 was composed of 30% shiner perch (*Cymatogaster aggregata*), 19% sculpin (*Cottus and Leptocottus spp.*), 36% salmonids, and numerous other species. Among salmonids, hatchery Chinook were the most numerous, followed by chum, pink (*O. gorbuscha*), unmarked Chinook, hatchery and unmarked coho (*O. kisutch*), cutthroat (*O. clarki clarki*), and steelhead (*O. mykiss*) (Table 2). Based on Chinook mark rates at Nisqually hatcheries (Table 3) and total catch, an estimated 14, 25, and 19% of the unmarked Chinook salmon caught were of hatchery origin in years 2002, 2003, and 2004 respectively.

Peak timing of the species caught during sampling differed, but there was considerable overlap among species, with peak total catch occurring in May – June (Figure 2). Average CPS of hatchery Chinook was highest in May (Figure 2), immediately following hatchery releases into the Nisqually River that occurred each year between early May and early June (Table 3). Hatchery Chinook were less abundant in June and almost absent in subsequent months. Unmarked Chinook were present in the catch throughout the months sampled (Feb. – Oct.) but were most abundant from late February through June (Figure 2). Chum salmon were present in the sampling areas from March to July, and peaked in May.

There was evidence of variability in average timing among the 3 sampling years for unmarked Chinook ($p < 0.0001$), hatchery Chinook ($p = 0.007$) and chum ($p = 0.005$), but some of this variability could be due to differences in sampling season length between years. Unmarked Chinook were, on average, caught 24 days earlier than hatchery Chinook in all years. This difference was significant in 2003 ($p < 0.0001$) and 2004 ($p = 0.0002$) but not in 2002 ($p = 0.65$). When analyzed by zone, unmarked Chinook were earlier than hatchery Chinook in the fresh and forested zones but had similar average timing in the transition, marsh, and delta zones. This pattern did hold true in 2003, when unmarked Chinook were on average over a month earlier than hatchery Chinook in the RSS and MCA marsh and delta zones (Figure 3). Chum did not show a consistent pattern of average timing across zones (Figure 4).

Utilization of the different habitat zones varied among the salmon species examined (Figure 4). Regression results (excluding the nearshore zone) showed a marginally significant zone effect for unmarked Chinook ($p = 0.059$), and a significant effect for hatchery Chinook (0.0006) and for chum ($p = 0.012$). Unmarked Chinook average CPS was significantly ($p < 0.05$) higher in the fresh, forested, transition, and RSS marsh zones than in the delta. Average hatchery Chinook CPS was significantly greater in the transition zone than all other zones except NIS marsh and RSS marsh, and was significantly greater in NIS marsh than in the fresh and forested zones. Chum salmon were significantly less abundant in the NIS marsh zone than in all other zones, and were also significantly more abundant in fresh and forested zones than in the MCA marsh.

A total of 759 unmarked Chinook, 1008 hatchery Chinook, and 846 chum were measured. Average lengths for chum, unmarked Chinook, and hatchery Chinook were 49, 77, and 92 mm respectively. Hatchery Chinook were on average 15mm longer than unmarked Chinook ($p < 0.0001$) but did not have significantly different variance in length ($p = 0.11$) (Figure 5). Lengths of unmarked Chinook, hatchery Chinook, and, to a lesser extent, chum increased with time (Figure 6) across all zones.

A total of 140 lethal Chinook samples were taken for CWT analysis to determine the hatchery of origin. The majority of the Chinook CWTs sampled were from Nisqually River hatcheries ($n = 116$), but 17% ($n = 24$) of the tags read came from outside the Nisqually watershed. Some of these Chinook were released from hatcheries in South Puget Sound watersheds, including the Deschutes River ($n = 2$) and Chambers Creek ($n = 9$), and some were released from Central Puget Sound watersheds including the Puyallup R. ($n = 8$ spring Chinook from the White River hatchery, $n = 2$ from Voights Creek hatchery, $n = 1$ from Cowskull acclimation pond), and the Duwamish River ($n = 2$). Of these Chinook from hatcheries outside of the Nisqually watershed, 42% were caught in the RSS marsh zone, 38% in the delta, 13% in the NIS marsh, and 4% in each of the MCA marsh and nearshore zones. Some (39%) of the out of basin hatchery Chinook were captured on or before the end of their release period (releases lasted from 1-27 days), while the remaining fish were caught from 12-61 days after the end of the release period (average 31 days). The Chinook from Nisqually hatcheries were caught in the marsh (NIS 57%, RSS 14%, MCA 16%), transition (23%), forested (9%), and fresh (8%) zones. Most (69%) of the Nisqually hatchery Chinook were caught on or before the end of their release period (releases lasted from 19-34 days), while the remaining tagged Nisqually Chinook were caught from 1 to 9 days from the last date of release (average 6 days).

Table 2. Species caught in order of declining abundance. Other species (including steelhead) that comprised less than 0.1% of the catch are not included. Annual catch and catch per set are shown along with the total catch for 2002-4 for each species and the percentage that species total catch was of the entire catch.

	Shiner Perch	All sculpin species	Hatchery Chinook	Chum	Pink	Starry Flounder	Unmarked Chinook	Hatchery Coho	Mountain Whitefish	Sand Lance	Pacific Herring	Smelt	Unmarked Coho	Largescale Sucker	Cutthroat
2002 Catch	3361	1403	1683	1174	0	717	283	4	89	41	1	26	105	10	39
2002 CPS	40.5	16.9	20.3	14.1	0	8.6	3.4	0.0	1.1	0.5	0.0	0.3	1.3	0.1	0.5
2003 Catch	5035	4183	3033	1429	0	484	829	54	26	694	139	409	189	16	16
2003 CPS	28.4	23.6	17.1	8.1	0	2.7	4.7	0.3	0.2	3.9	0.8	2.3	1.1	0.1	0.1
2004 Catch	7260	4360	3960	1790	2218	972	625	1494	1057	349	705	49	55	295	20
2004 CPS	26.5	15.9	14.5	6.5	8.1	3.6	2.3	5.5	3.9	1.3	2.6	0.2	0.2	1.1	0.1
Total Catch	15656	9946	8676	4393	2218	2173	1736	1552	1172	1083	845	484	349	321	75
% of Catch	30.9	19.6	17.1	8.7	4.4	4.3	3.4	3.1	2.3	2.1	1.7	1.0	0.7	0.6	0.15

Table 3. Fall Chinook hatchery releases between 2002 and 2004 in the Nisqually River and McAllister Creek.

Year	Release Area	Number Released	Release Period	Release Type	% CWT or clip *	Release Stage
2002	McAllister Creek	385749	Feb 12 -Feb 28		95.1%	Yearling
2002	McAllister Creek	1371752	May 13 - Jun 6		98.1%	Smolt
2002	Nisqually River	4097466	May 7 - Jun 6	Volitional/ Forced	97.5%	Fingerling
2003	Nisqually River	3514024	May 7 - Jun 11	Volitional	93.5%	Fingerling
2004	Nisqually River	4166184	May 6 - Jun 4	Volitional	97.1%	Fingerling

*% CWT or clip' column shows the percentage of fish that had a CWT or an adipose fin clip. This is the percentage of hatchery releases that could be correctly identified as hatchery fish during field sampling.

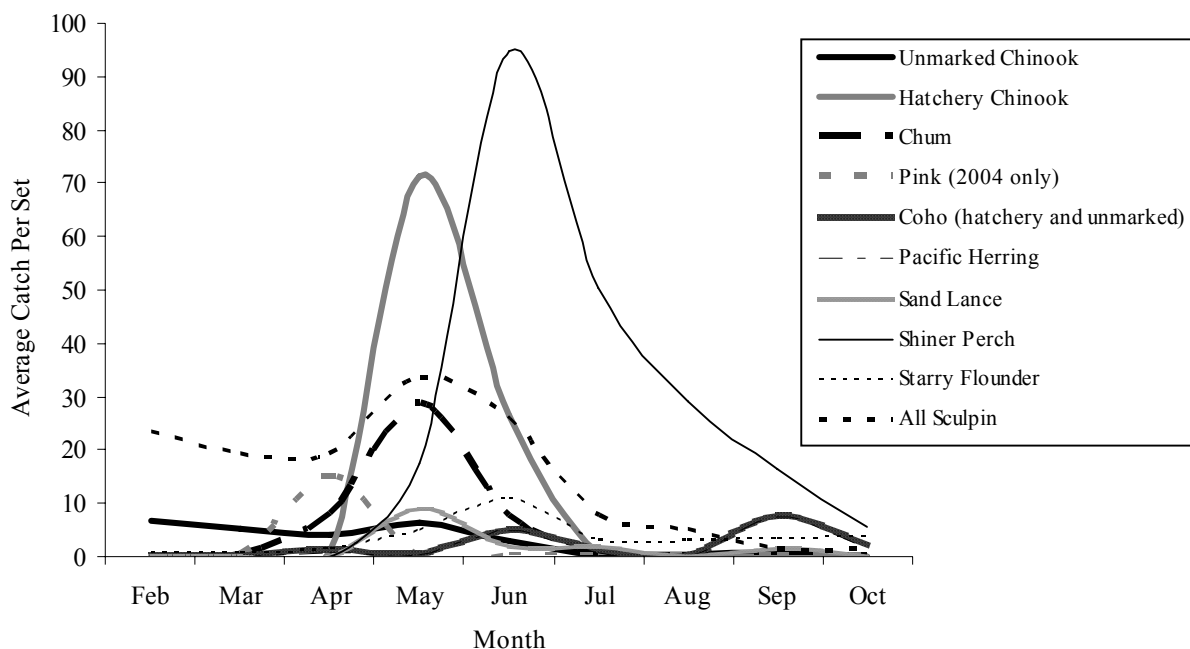


Figure 2. Average catch per set by month, all zones and years combined.

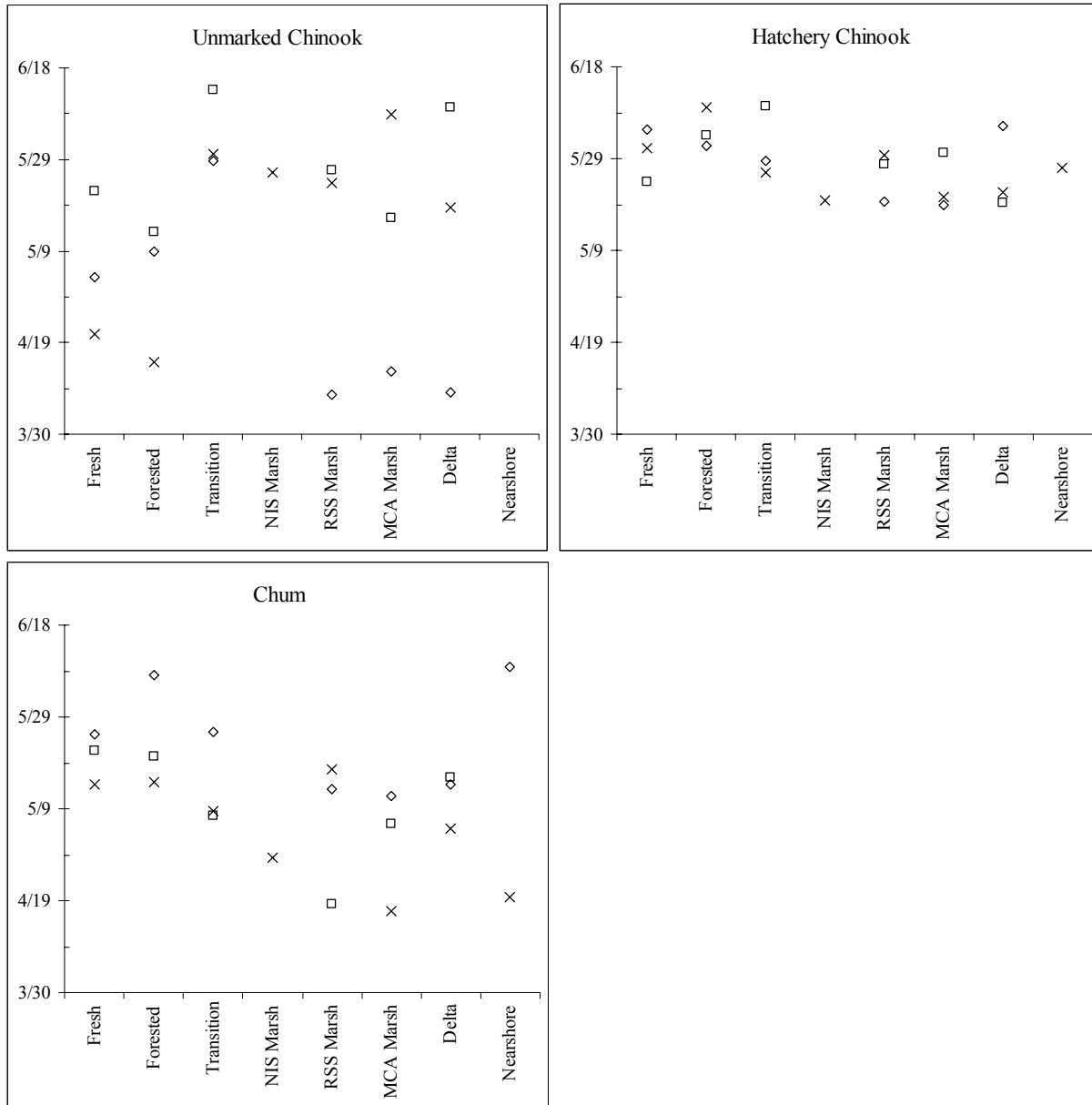


Figure 3. Average timing (weighted average by number caught) in 8 zones for unmarked and hatchery Chinook and chum. 2002 data are shown with squares, 2003 data are shown with diamonds, and 2004 data are shown with x.

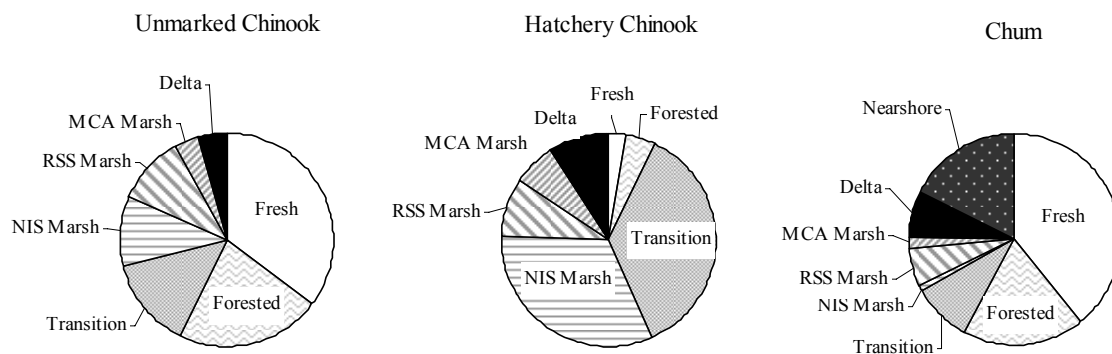


Figure 4. Average Proportional average catch per set by zone for unmarked Chinook, hatchery Chinook, and chum.

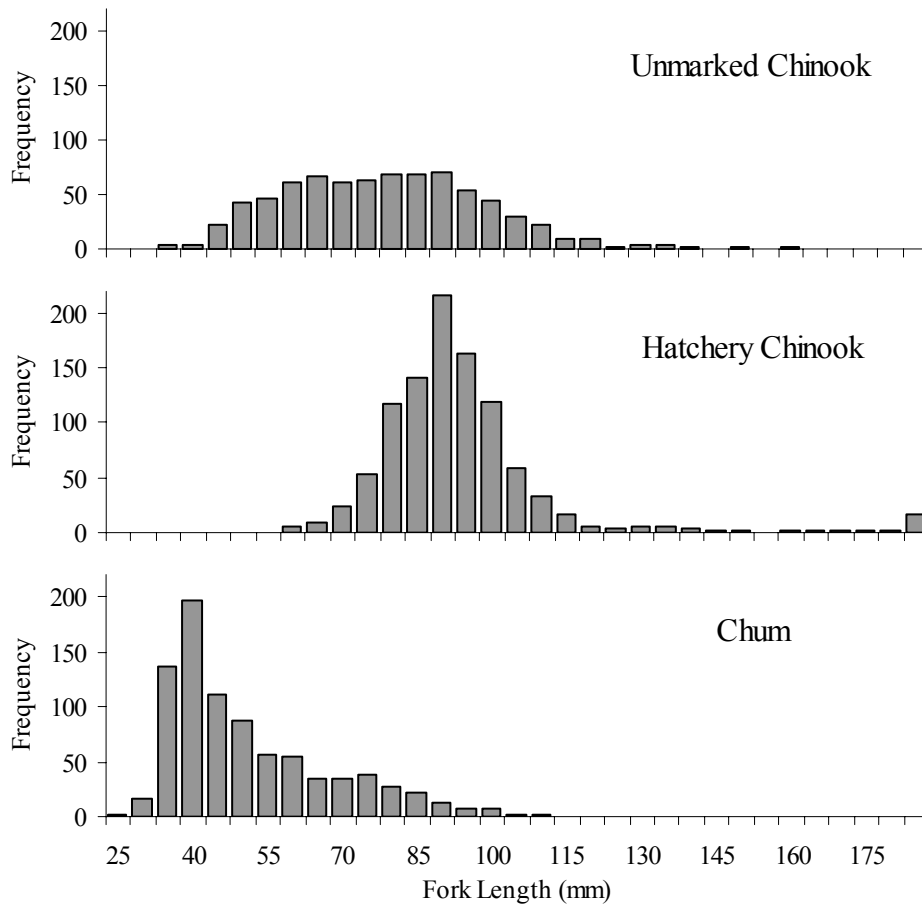


Figure 5. Frequencies of lengths measured for unmarked Chinook, hatchery Chinook, and chum. Data from all zones and years were combined. McAllister Cr. yearlings were included.

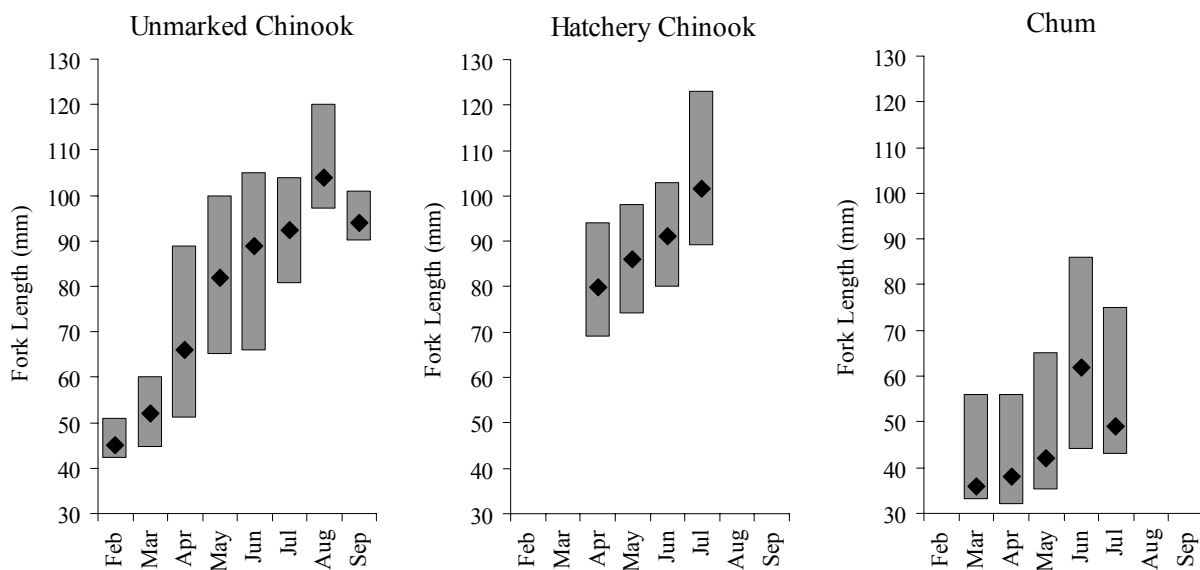


Figure 6. Monthly median length (black diamonds) and range from 10th to 90th percentile in fork length (gray bars) for unmarked Chinook, hatchery Chinook, and chum. Data from all zones and years were combined. McAllister Creek yearlings (released only in 2002) were excluded.

Discussion

Three years of fish sampling in the Nisqually Estuary have indicated that spatial and temporal distribution patterns vary among hatchery and unmarked Chinook, chum, and other species in the estuary but there is also considerable overlap in habitat use among these species. Most chum salmon were caught between April and May, on average later than unmarked Chinook and earlier than hatchery Chinook, and were most abundant in fresh, forested, and nearshore zones. Following hatchery Chinook releases in the Nisqually River in May, catch data indicated that the majority of these fish spent little time in the fresh and forested zones, but that they were caught in high numbers in the saltier zones during May and June, especially in the lower Nisqually River (transition and NIS marsh zones). Unmarked Chinook salmon, which are much less numerous in the system, had a broader distribution in time and were caught prior to, during, and after the period of hatchery Chinook presence. Unmarked Chinook also appeared to have a broader or more even geographic use of the system. The diversity of unmarked Chinook timing, spatial distribution, and size complicates interpretation of utilization patterns and suggests that there may be various Chinook life histories present in the Nisqually Estuary, as has been documented in the Skagit River (Beamer et al. 2000). In contrast, hatchery Chinook displayed a shorter period of presence in the estuary and a narrower range of length than unmarked Chinook, suggesting a less varied use of the estuary. Future work, including otolith analyses may shed more light on the life history diversity of Nisqually Chinook.

Beach seining data indicated extensive co-occurrence between chum, unmarked, and hatchery Chinook, especially between unmarked and hatchery Chinook in the transition and marsh zones. The impacts of these co-occurrences are unknown but are presumed to be greatest where and when hatchery Chinook are most abundant. In the Nisqually Delta this would occur in the transition and marsh zones during May-June.

The potential that portions of the unmarked Chinook caught were actually accidentally unmarked hatchery releases introduces the possibility that patterns in unmarked Chinook timing and distribution may not accurately represent those of naturally spawned Chinook. However, data prior to hatchery releases in May should be unbiased, and the application of hatchery Chinook mark rate correction factors did not substantially alter the results. Another factor complicating the analysis is the presence of non-natal salmon in the Nisqually estuary. CWT analysis showed that Chinook released from hatcheries in other watersheds are common in the lower estuary, and presumably naturally spawned Chinook from other watersheds may use the estuary to a similar extent.

This baseline research is a critical step in developing a multispecies conceptual model of fish ecology in the lower Nisqually River and estuary. Such a model should aid in predicting fish responses to restoration of estuarine habitats. For example, an increase in the area of NIS marsh and transition zones following large scale restoration in the delta would be predicted to benefit both naturally spawned and hatchery Chinook, by increasing capacity and reducing co-occurrence pressure in these 'preferred' habitat zones. As another example, restoration of the forested riverine tidal habitat would be expected to benefit a large proportion of natural origin Chinook and chum and a small proportion of hatchery Chinook. Baseline research has also been important for identifying data gaps in the model. A case in point is the apparent importance of the nearshore zone directly adjacent to the Nisqually Delta for chum (Figure 4), which can only be verified by intensive sampling throughout this zone. Analyses of Chinook otoliths will also be needed to more fully understand the underlying life history patterns that combine to yield the complex timing and distribution patterns observed. Future research will also examine the role of abiotic factors like river flow, temperature, and salinity as mechanisms for determining the spatial distribution of marked and unmarked Chinook, as well as other fishes, in the estuary.

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